INTERNATIONAL TRANS-ANTARCTIC SCIENTIFIC EXPEDITION (ITASE)

From its original formulation in 1990, the International Trans-Antarctic Scientific Expedition (ITASE) has coordinated the efforts of scientists from several nations to collect and interpret a continent-wide array of environmental parameters. This cooperative endeavor is geared to produce an improved description and understanding of environmental change in Antarctica over approximately the last 200 years. These original ITASE scientific objectives have been adopted as key science initiatives by both the International Geosphere-Biosphere Program (IGBP) and the Scientific Committee on Antarctic Research (SCAR).

In 1996 an NSF workshop was held to develop a Science and Implementation Plan for the United States contribution to ITASE (called "U.S. ITASE"). Because of the long-standing U.S. research effort in West Antarctica, U.S. ITASE chose to focus its activities there. At the U.S. ITASE workshop, participants developed a multi-disciplinary research plan that integrates different approaches to environmental research. The primary scientific lenses through which West Antarctica is being examined are meteorology, remote sensing, ice coring, surface glaciology, and geophysics. The plan has four phases:

• In Phase 1 meteorological modeling and remote sensing was used to plan sampling strategies in support of U.S. ITASE's major objectives.

• Phase 2 initiates ground-based sampling over four study areas (corridors). Notwithstanding the broad spatial sampling of West Antarctica that was proposed, the logistic requirements for this sampling are modest and highly efficient.

• Phase 3 will continue ground-based sampling at a limited number of key sites where monitoring is required.

• Phase 4 follows through with data interpretation and modeling.

The United States component of ITASE (which has established a wide range of general scientific objectives) is trying to refine answers to the following questions:

• At what rate is the mass balance changing over West Antarctica?

• How do the major oceanic and atmospheric circulation systems(for example, ENSO) influence the moisture flux over West Antarctica?

• How and why does climate (that is, temperature, accumulation rate, atmospheric circulation) vary over West Antarctica on seasonal, inter-annual, decadal and centennial scales?

• What is the frequency, magnitude, and effect (local to global) of any extreme climate events recorded in West Antarctica?

• What is the impact of anthropogenic activity (for example, ozone depletion, science work, airborne pollutants) on the climate and atmospheric chemistry of West Antarctica?

• How much has biogeochemical cycling of sulfur, nitrogen and carbon, as recorded in West Antarctica, varied over approximately the last 200 years?

Radar studies of internal stratigraphy and bedrock topography along the U.S. ITASE traverse.
Robert W. Jacobel, Saint Olaf College.

The U.S. component of the International Trans-Antarctic Scientific Expedition (U.S. ITASE) conducts radar studies to determine the internal stratigraphy and bedrock topography of the terrain along the traverses. To help in the selection of core sites as the traverse proceeds, the radar provides immediate information (to those working in the field) on ice thickness and the structure of internal layers. These data can also be used to site deeper, millennial scale cores (planned at less frequent intervals along the traverse) and to provide a context for selecting the location of the deep inland core (planned for the future). In addition to mapping the traverse route, radar is used to examine a grid surrounding each of the core locations, to better characterize the accumulation and bedrock topography in each area.

This radar system works as a complement to that operated by the Cold Regions Research and Engineering Laboratory (CRREL). Theirs is a high-frequency radar, most suited to the shallower portion of the record down to approximately 60 meters (m); it can detect near-surface crevasses. Our radar system is most sensitive at depths below 60 m and is able to depict deep bedrock and internal geological layers deep into the ice. (IU-133-O)

Science Management for U.S. ITASE.
Paul A. Mayewski and Mark S. Twickler, University of New Hampshire.

The Science Management Office (SMO) coordinates the effort developed for U.S. ITASE, the broad aim of which is to develop an understanding of the last 200 years of west antarctic climate and environmental change. ITASE is a multidisciplinary program integrating remote sensing, meteorology, ice coring, surface glaciology, and geophysics. To marshal this effort, SMO runs a series of annual workshops to coordinate the science projects that will be involved in ITASE. They also establish and operate the logistics base that supports ground-based sampling in West Antarctica. (IU-153-A)

U.S. ITASE Glaciochemistry.
Paul A. Mayewski and Loren D. Meeker, University of New Hampshire.

Among the research targets for scientists in U.S. ITASE are the impact of anthropogenic activity on the climate and atmospheric chemistry of West Antarctica and the variations in biogeochemical cycling of sulfur and nitrogen compounds over the last 200 years.

Begun during the 1999-2000 austral summer, this 5-year project focuses on glaciochemical analyses of the major anions and cations to be found in shallow and intermediate depth ice cores collected on the U.S. ITASE traverses. The ionic composition of polar ice cores provides one of the basic stratigraphic tools for relative dating. These data can also be used to document changes in chemical-species source emissions, which in turn facilitate mapping and characterization of the major atmospheric circulation systems affecting the West Antarctic Ice Sheet. (IU-153-B)

Snow and firn microstructure and transport properties: U.S. ITASE.
Mary R. Albert and Robert E. Davis, U.S. Army's Cold Regions Research and Engineering Laboratory.

Not all valuable data are buried deep within the ice. The microstructure and bulk properties of snow and firn near and at the surface control the air/snow/firn transport processes; that is, how heat, vapor, and chemical species in air are incorporated into snow and firn. Since many of the snow and firn properties will also affect how radiation behaves across different parts of the electromagnetic spectrum, such field measurements provide a valuable baseline profile against which to range complementary efforts that use remote sensing to map the spatial variations of snow, firn and ice properties.

This project does the field and lab work to characterize snow and firn properties along the U.S. ITASE traverses in West Antarctica. We provide field measurements of snow and firn properties near the surface (down to 2 meters), including surface roughness, permeability, density, grain size, surface-to-volume ratio, and tortuosity. In the laboratory, firn cores from as deep as 20 meters will be analyzed for these same properties and for their microstructure. Ultimately, we will develop a transport model to elucidate the nature of the air/snow/firn exchange and the firnification process at the various sites along the U.S. ITASE traverse. (IU-155-O)

Hydrogen peroxide, formaldehyde, and sub-annual snow accumulation in West Antarctica: Participation in west antarctic traverse.
Roger C. Bales, University of Arizona.

Atmospheric photochemistry leaves valuable traces in snow, firn and ice; it has been verified that the efficiency of atmosphere-to-snow transfer, and the preservation of hydrogen peroxide and formaldehyde, are both strongly related to temperature and also to the rate and timing of snow accumulation. Thus, measurements of these components in the firn and atmosphere will provide data needed to study changes in tropospheric chemistry of the boundary layer over West Antarctica.

This project will collect samples and take atmospheric measurements along the U.S. ITASE traverses. The wide-ranging extent of these traverses will train the scientific lens upon a variety of locations, covering much of the west antarctic region and reflecting a range of different depositional environments.The study of atmospheric chemistry requires good estimates of the inter-annual patterns of snow accumulation at sub-annual resolution in the pits and cores.

We will measure the concentration of seasonally dependent species (including hydrogen peroxide, nitrate and chloride) on all samples. Supplemented by stable isotope and ionic analyses done by others, these data will provide a highly resolved accumulation record. We will then use a recently developed, physically based, atmosphere-to-snow transfer model in order to elucidate the photochemistry that led to the concentrations in the snow/firn.

These snow chemistry data will also shed light on the interannual variability of snow accumulation over a wide area of West Antarctica. In addition, data we develop on current atmospheric levels of hydrogen peroxide, higher peroxides such as methylhydroperoxide, and formaldehyde will constrain model boundary conditions and the state of photochemistry in the austral summer. (IU-158-O)

Mass balance and accumulation rate along U.S. ITASE routes.
Gordon S. Hamilton, University of Maine.

The polar ice sheets - and the snow falling on them - are both important components of the global hydrological cycle. Yet, because of their very large size and remote locations, we have only a limited understanding of their mass balance (rate of thickness change) or the spatial distribution of snow accumulation. Work conducted as part of the U.S. ITASE seeks to improve this understanding.

This 5-year project, which is beginning its third year, involves measuring the rate of ice-sheet thickening (or thinning) at selected sites along flow lines, on ice divides, and along elevation contours. The measurements compare the vertical velocity of ice (obtained from precise global positioning system surveys of markers buried 5-20 meters deep in the surface firn) with the local, long-term, average snow accumulation rate that has been derived from ice-core stratigraphy. Earlier work demonstrates that very precise rates of thickness change can be measured using this technique.

We are also studying spatial variations in accumulation rates, probing the link between snow accumulation and surface topography. Continuously operating, autonomous instruments will be deployed at several closely spaced sites that have very different slope gradients. The instruments will record snow accumulation, wind speed and direction, and firn compaction and temperature. These results will enable us to test hypotheses of the physical processes of snow deposition and erosion.

We shall also investigate the ice flow effects on accumulation rates derived from U.S. ITASE ice-core records. At sites along flow lines, ice cores record the integrated accumulation rate history, for a certain distance up-glacier, of the core site. Changes in surface topography along this flow line will lead to apparent accumulation rate variations in the ice-core record. By studying local ice dynamics (for example, horizontal velocities, surface slope) around each ice core site, we will be able to better understand why the accumulation rate varies in the core records. (IU-178-O)

The physical properties of the U.S. ITASE ice cores.
Debra Meese, U.S. Army Cold Regions Research and Engineering Laboratory.

Our objective is to examine, measure and analyze the visual stratigraphy, physical, and structural properties of the U.S. ITASE ice cores spanning the last 200 years of snow accumulation in Antarctica.

• First, visual stratigraphy; this will delineate the annual layer structure for dating purposes and determine (to as great a depth as possible) the accumulation variability over the full length of a stratigraphically dated core.

• Second, depth-density profiles; the rate of snow and firn densification depends on both the in-situ snow temperature and the rate at which the snow is deposited. These data will be used to derive average snow accumulation rates for those sites where annual layer structure is difficult to decipher, or where stratigraphic analysis fails altogether.

• Third, the mean crystal size over the full length of a core; crystal growth is a strongly temperature-dependent process, and measurements to be made on ITASE cores will help to bridge a significant gap that exists in the mean annual temperature data between -31° and -50°C. Crystal size data can also be used (in conjunction with ice loads based on density profile measurements) to extract mean accumulation rates for those sites where stratigraphic dating of cores proves difficult or impossible to accomplish along the ITASE traverse routes; this is likely to occur at the sites where temperature is the lowest, and snow accumulates the least. (IU-193-O)

Stable-isotope studies at West Antarctic U.S. ITASE sites.
Eric Steig, University of Pennsylvania; James White and Christopher Shuman, University of Colorado-Boulder, Institute of Arctic and Alpine Research.

As participants in U.S. ITASE, we will perform stable isotope analyses of samples collected during the traverses in West Antarctica. Using instrumental and remote-sensing temperature histories, we will focus on the spatial and temporal distribution of oxygen-18 and deuterium in West Antarctica (where data are particularly sparse) and on the calibration of the isotope/climate relationship on a site-by-site basis.

Our objectives are to

• obtain detailed oxygen-18, deuterium, deuterium-excess, and stratigraphic histories in snowpits at most or all of the U.S. ITASE coring sites;

• provide direct calibration of the isotope/climate relationship at each site, through a combination of direct (automatic weather stations) and indirect (passive microwave satellite) temperature measurements;

• obtain isotope profiles covering the last 200 years; and

• use the results to provide climate histories at high temporal and broad spatial resolution across West Antarctica for the past two centuries.

These climate histories should provide the context to test relationships that have been proposed among isotopes, moisture source conditions, synoptic scale climatology, and site-specific meteorological parameters. They will also enhance our ability to interpret isotope records from older and deeper antarctic ice cores. (IU-193-O)

High-resolution radar profiling of the snow and ice stratigraphy beneath the U.S. ITASE traverses, West Antarctic Ice Sheet.
Steven Arcone, U.S. Army Cold Regions Research and Engineering Laboratory

Ice core measurements provide historical profiles of snow accumulation and chemistry only at the point where the core was drilled, which - along the U.S. ITASE traverses - is every 100 kilometers (km). Subsurface radar, by contrast, provides reflection profiles of continuous horizons, generally related to density and chemistry contrasts; but their continuity strongly suggests that they are isochronal (that is, demonstrate regularity of period). Thus they can be used to track particular years between core sites and to provide a broad and more meaningful average of year-to-year accumulation rates, given the time versus depth calibrations from the cores.

This project is tracking these reflection horizons between core sites using high-resolution ground-penetrating, short-pulse radar. Our main antenna system uses a pulse centered near 400 MHz, which provides vertical resolution of about 35 centimeters, and records reflections from a depth in firn of about 60 meters (m). During the first year of U.S. ITASE, we tracked some horizons for distances of more than 190 km and found depth variations as great as 22 m over a 5-km stretch. The variations are caused by surface topography, which affects local accumulation rates and ice movement.

We are also using a wide range of frequencies (as high as 10 GHz and as low as 100 MHz) to distinguish between conductivity and density as a cause of the reflections. The horizon tracking develops spatially averaged, historical accumulation rates; these can be correlated with GPS data to find the effects of topography upon local accumulation rates. In addition, the radar is also being used for advanced crevasse detection. (IU-311-0)